Water Resources on Guam:
Potential impacts and adaptive response to climate change for Department of Defense installations
RC-2340

Dr. Stephen B. Gingerich
U.S. Geological Survey

Brief to the Scientific Advisory Board
June 12, 2013

SERDP
DOD ▪ EPA ▪ DOE

Performers

Dr. Stephen B. Gingerich
Dr. Delwyn S. Oki

U.S. Geological Survey (USGS) Pacific Islands Water Science Center
Groundwater & surface-water modeling

Dr. Annamalai Hariharasubramanian
Dr. Kevin Hamilton
Dr. Yuqing Wang

University of Hawaiʻi-International Pacific Research Center (UH-IPRC)
Future climate modeling (typhoons, precipitation, temperature, etc.)

Dr. John W. Jenson
Dr. Mark A. Lander

University of Guam-Water & Environmental Research Institute
Physical & geological process measurements

Dr. Jay L. Banner

University of Texas-Austin
Geochemistry of hydrologic cycle

Dr. Melissa L. Finucane
Dr. Victoria Keener

Pacific Regional Integrated Sciences and Assessments (RISA), East-West Center (EWC)
Communication & stakeholder engagement

Problem Statement

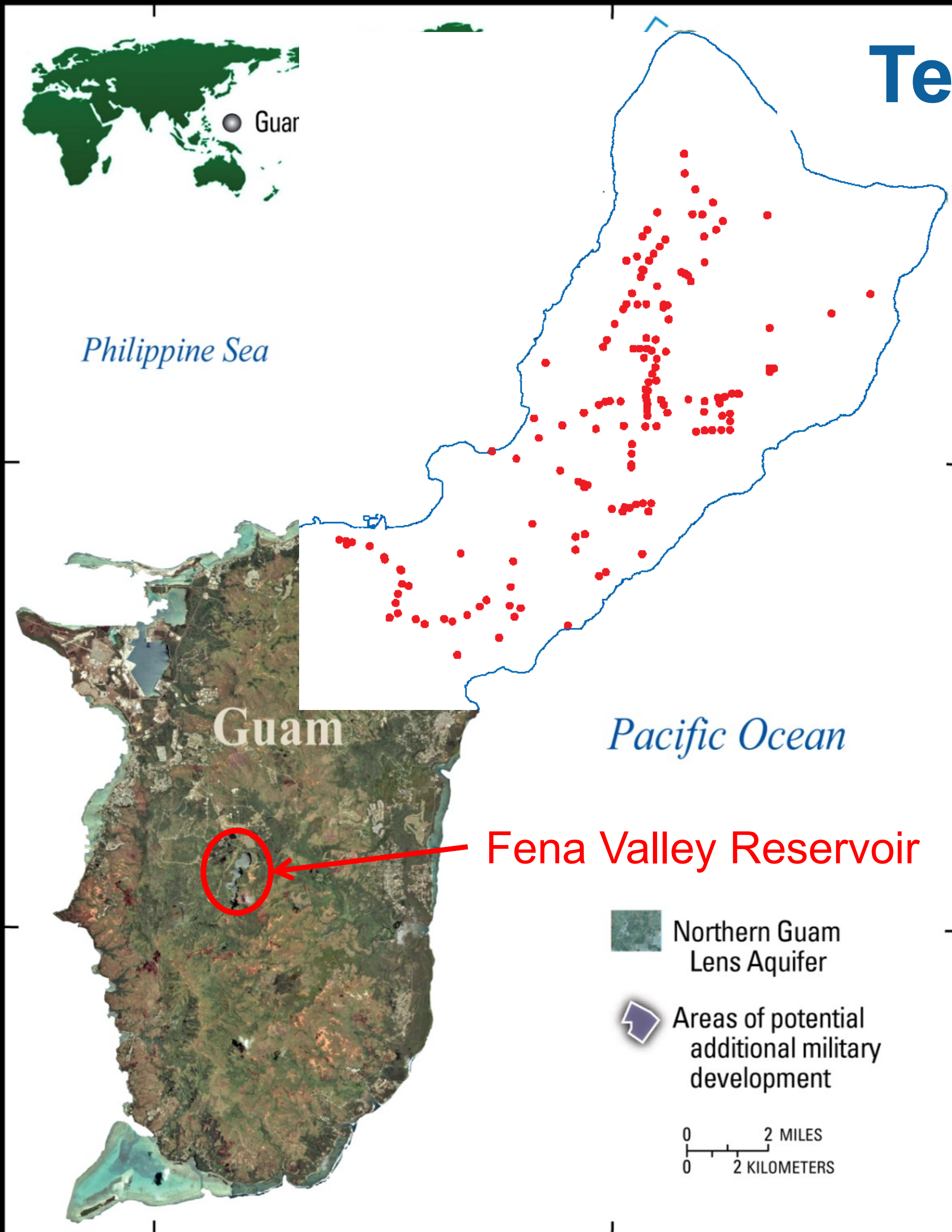
- The DoD relies on surface water & groundwater for operations at its Guam installations
- Demands are projected to increase & the effects of climate change may limit the water resources available to meet these demands on this isolated island
- Research is needed to quantify future water availability & describe adaptive strategies to minimize the adverse impacts on DoD installations

Technical Objective

For a range of climate-change scenarios on Guam we will:

- Evaluate how streamflow, sediment loads, & turbidity will be modified & affect surface-water availability
- Assess how groundwater recharge & salinity will be modified
- Define impacts to DoD infrastructure supplying surface water & groundwater & highlight adaptive strategies to maximize the water resources
- Evaluate & implement effective communication strategies to inform water managers about potential impacts & adaptive strategies

Technical Background



Northern Guam

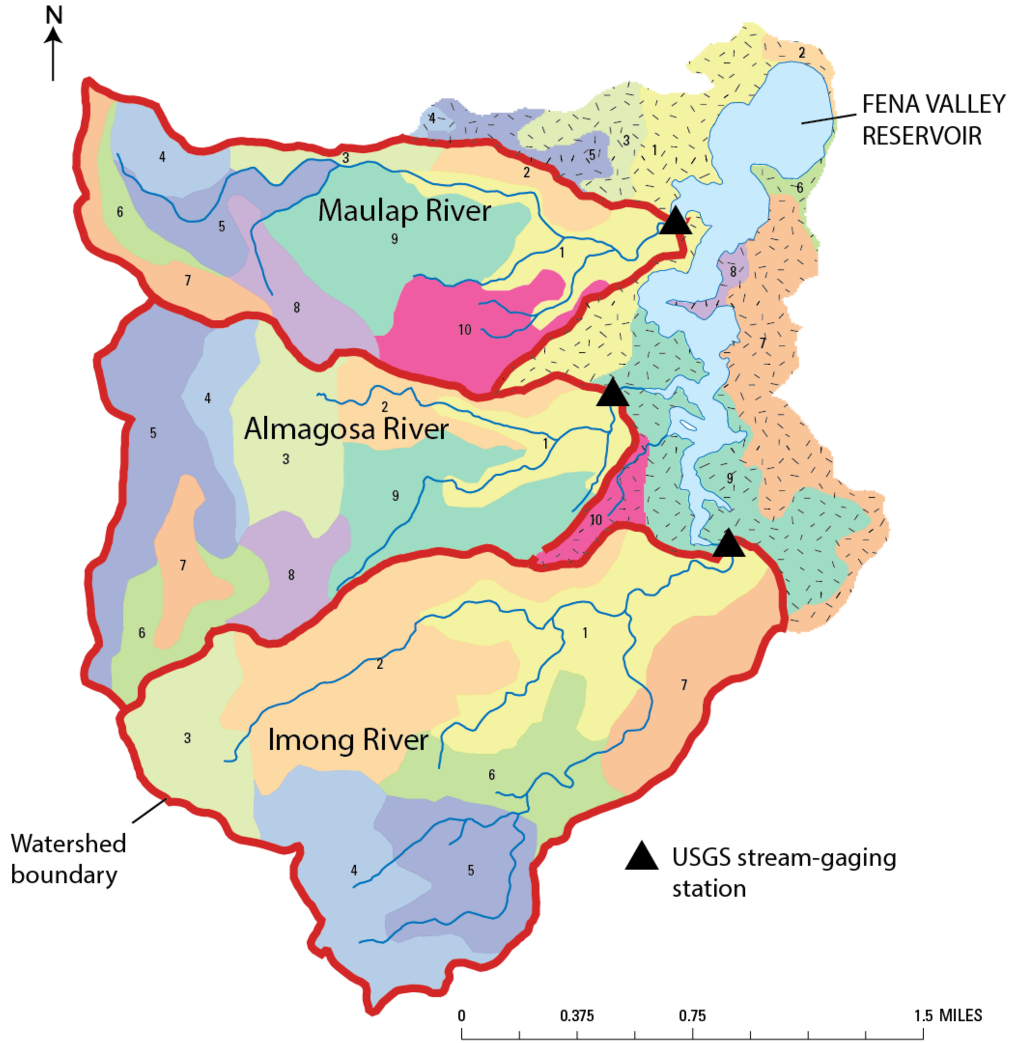
- Groundwater domain
- Karst limestone aquifer
- "Urbanized"
- 40 Mgal/d from about 150 public & DoD wells
- Water supply vulnerable to droughts & saltwater intrusion

Southern Guam

- Surface-water domain
- Weathered volcanics & limestone
- Rural
- 11 Mgal/d from Navy's Fena Valley Reservoir & 2 smaller public sources
- Water supply vulnerable to droughts & frequent typhoons & tropical storms

Technical Background-Fena Valley Watershed

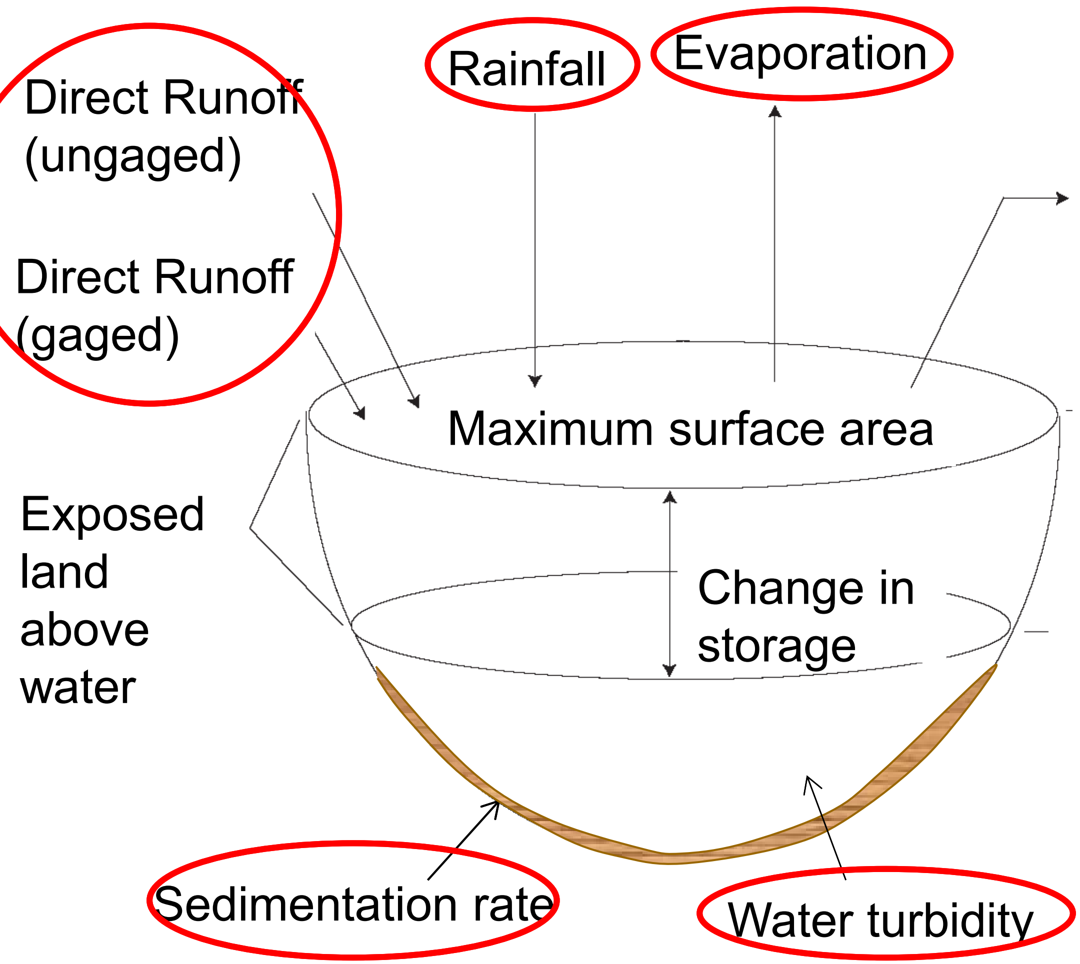
- Existing USGS Precipitation-Runoff Modeling System (PRMS)
- Calibrated using USGS stream-gaging stations & rainfall stations
- Limited areal extent
- Factors vulnerable to climate change
  - Vegetation
  - Rainfall
  - Evapotranspiration
  - Runoff
  - Extreme event size & frequency



Three main watersheds supplying Fena Valley Reservoir in Southern Guam

Technical Background-Fena Valley Reservoir

Affected by climate change



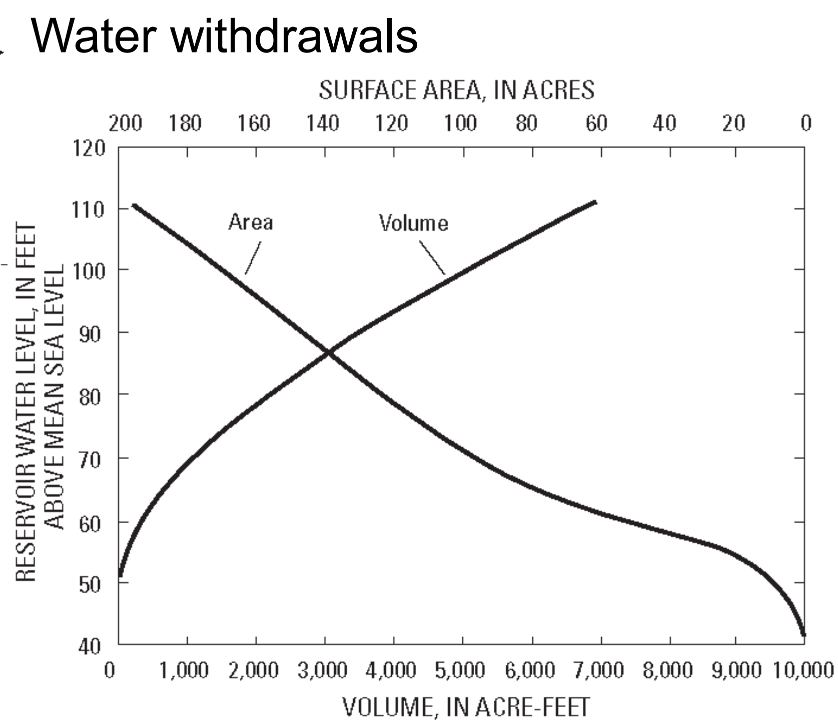


Figure 27. Water level-surface area and water level-capacity curves for the Fena Valley Reservoir, Guam, 1990 (Nakama, 1992).

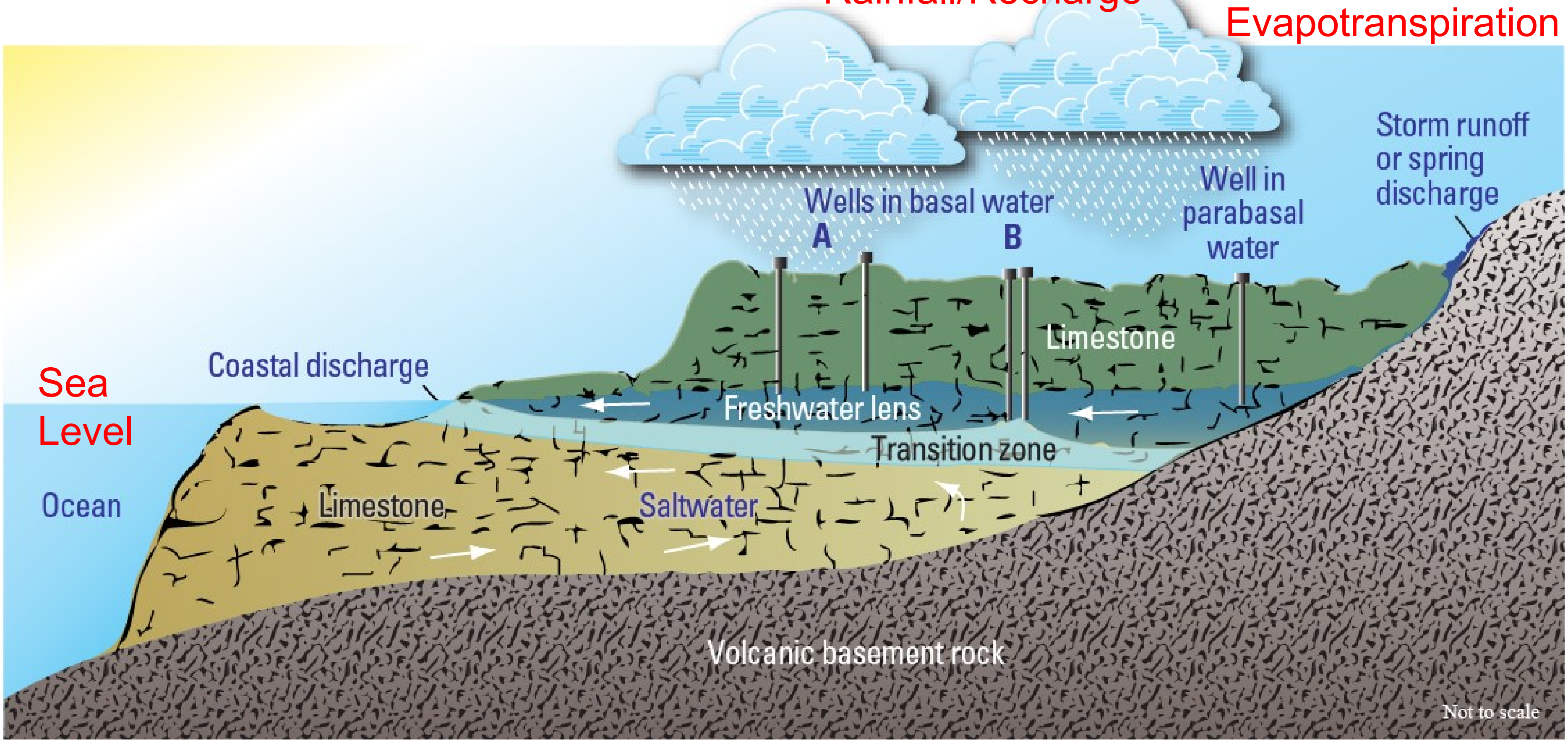
Technical Background-Northern Guam Lens Aquifer

Affected by climate change

Rainfall/Recharge

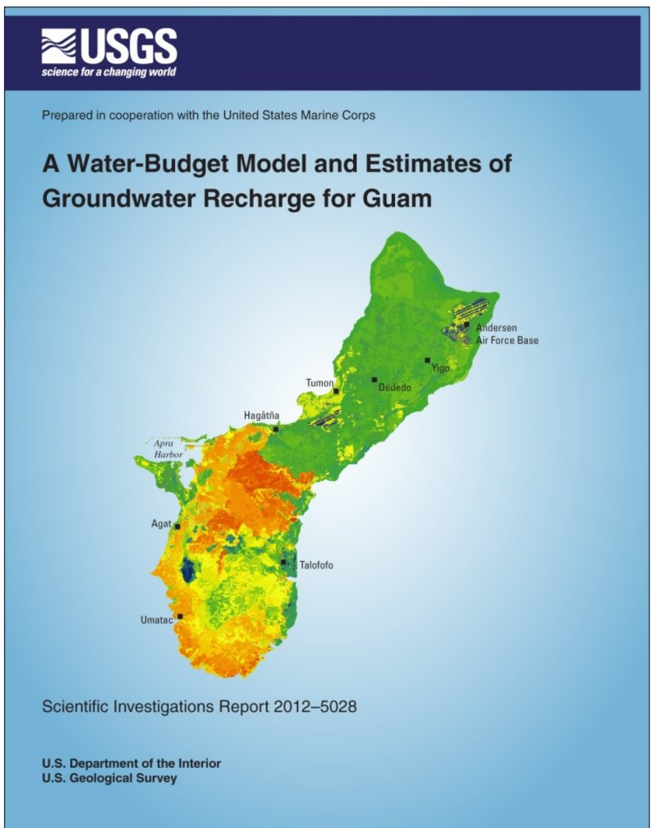
Evapotranspiration

Sea Level

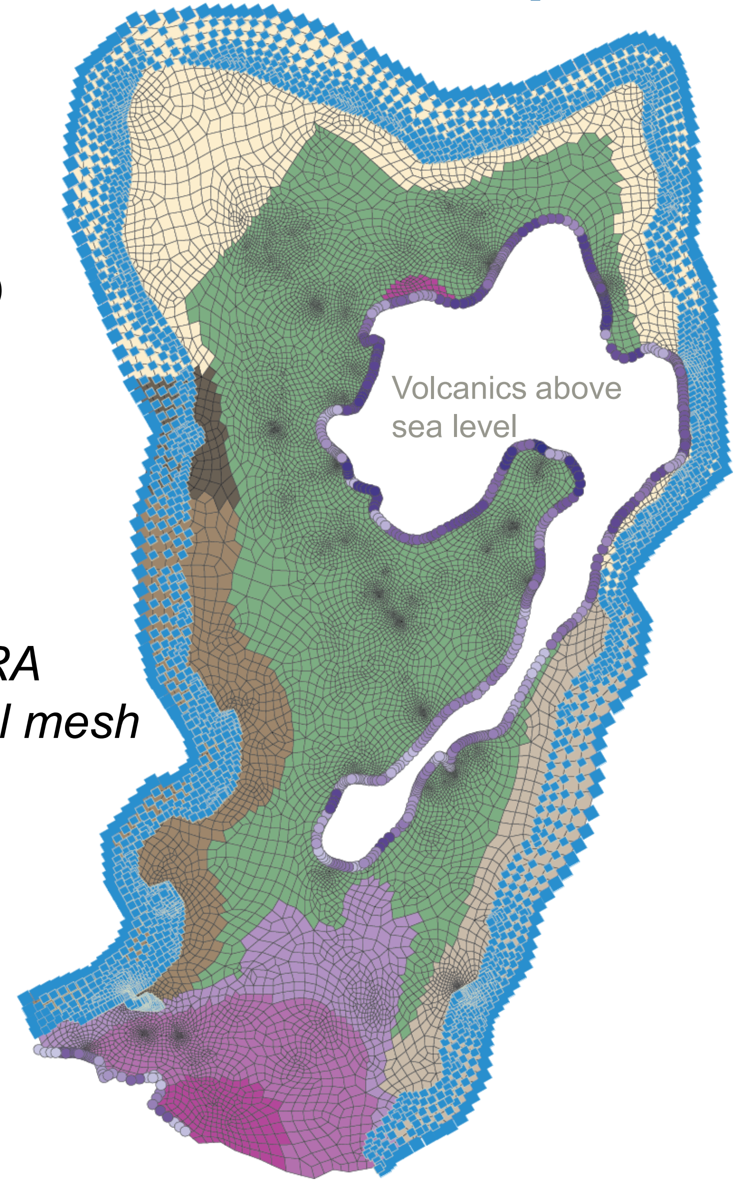


Technical Background-Northern Guam Lens Aquifer

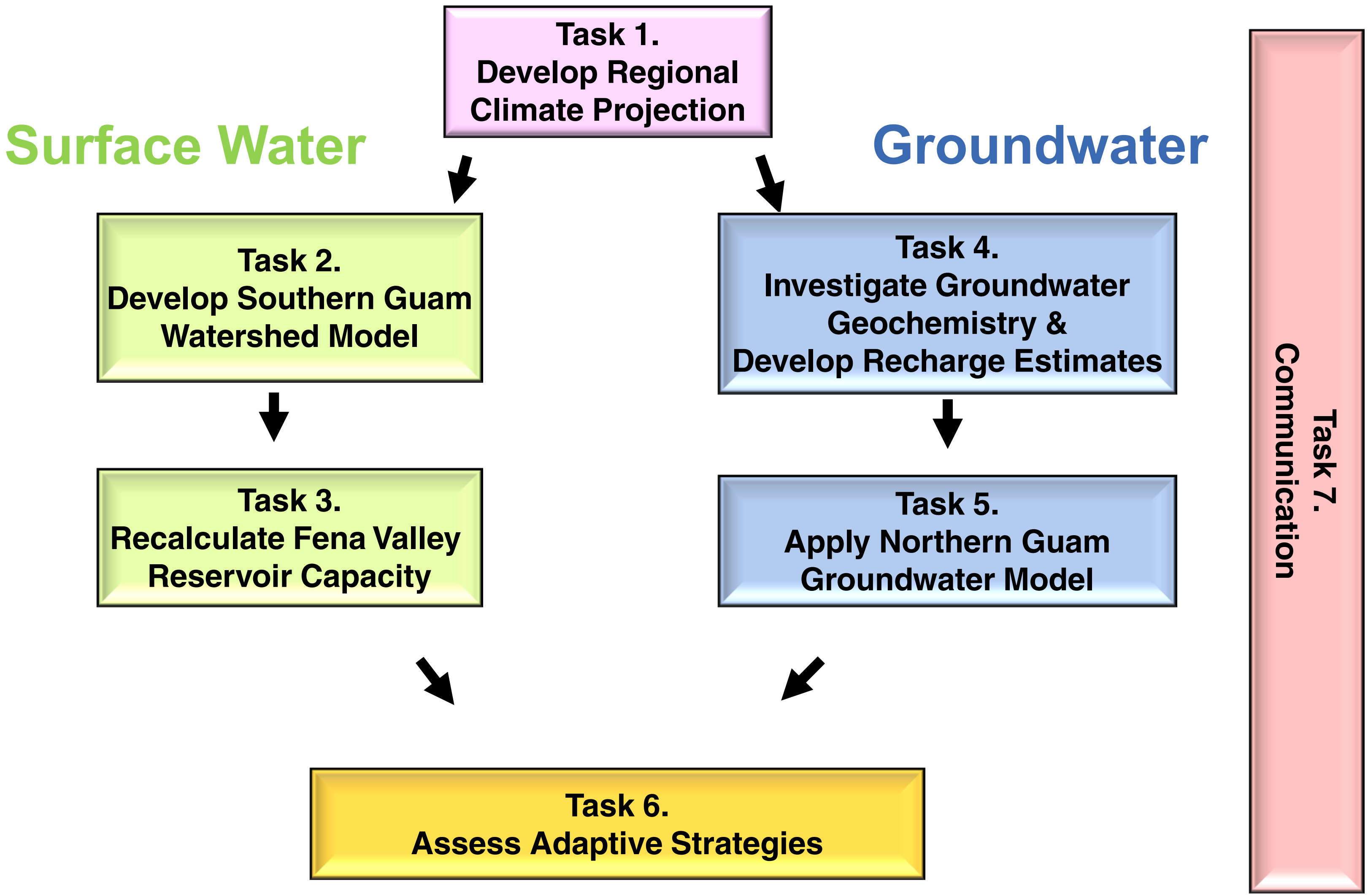
- PI Gingerich led USGS study from 2010–13, funded by U.S. Marine Corps
- Estimated groundwater recharge
- Developed numerical groundwater model using **S**aturated-**U**nsaturated **TRA**nsport code (**SUTRA**)



SUTRA Model mesh

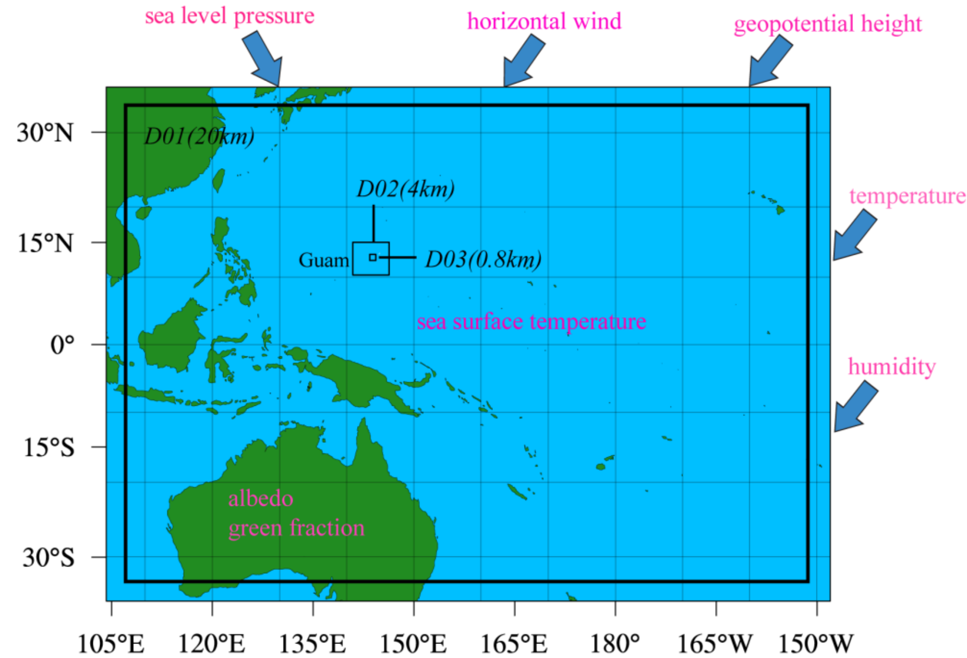


Technical Approach



Task 1: Climate Projection

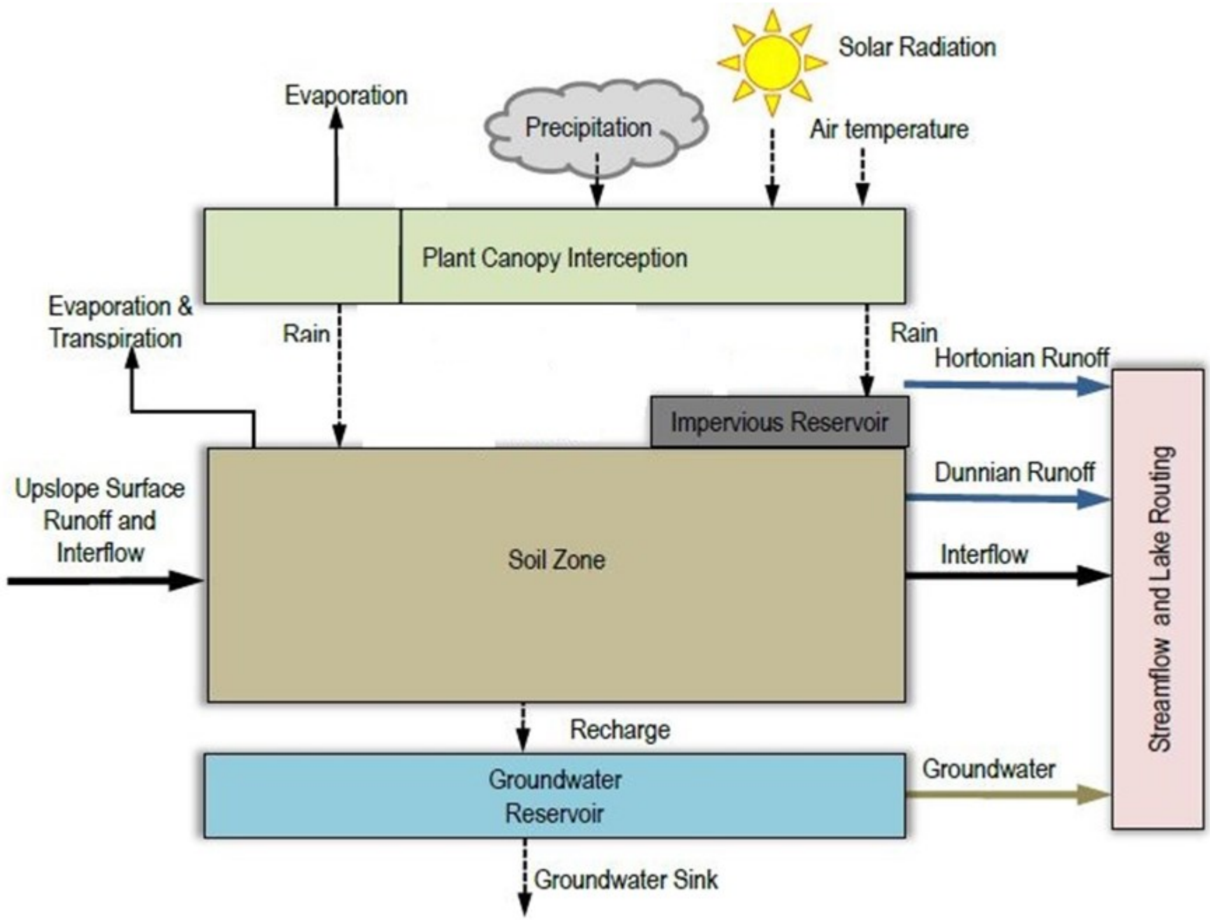
- Future climate may have different daily & drought conditions & typhoon frequency & intensity (typhoons produce about 12% of rainfall)
- Assess Coupled Model Intercomparison Project (*CMIP5*) simulations – choose "best models" matching rainfall & sea-surface temperature at coarse resolution
- Design experiments with fine-resolution (1-3 km) regional model
    - UH-IPRC regional atmospheric model (iRAM) to improve understanding of long-term changes in tropical cyclone behavior
    - Atmospheric circulation, clouds, & rainfall over tropical & subtropical regions
- Examine changes in occurrence probability of storm characteristics
- TRACK program will objectively identify features that are tracked through the time sequence to produce feature trajectories



- Produce a range of estimates of rainfall, wind speed, evaporation, etc. to feed into surface-water & groundwater-recharge models

Task 2: Southern Guam Watershed Model

- Current USGS PRMS model can be improved & expanded to other watersheds providing surface water in southern Guam
- Calibrate model with USGS streamflow & rainfall data in gaged basins
- Supplement with Next-Generation Radar (NEXRAD) rainfall data for ungaged areas
- Evaluate streamflow response to climate change using calibrated model to provide estimates of a range of future streamflow conditions

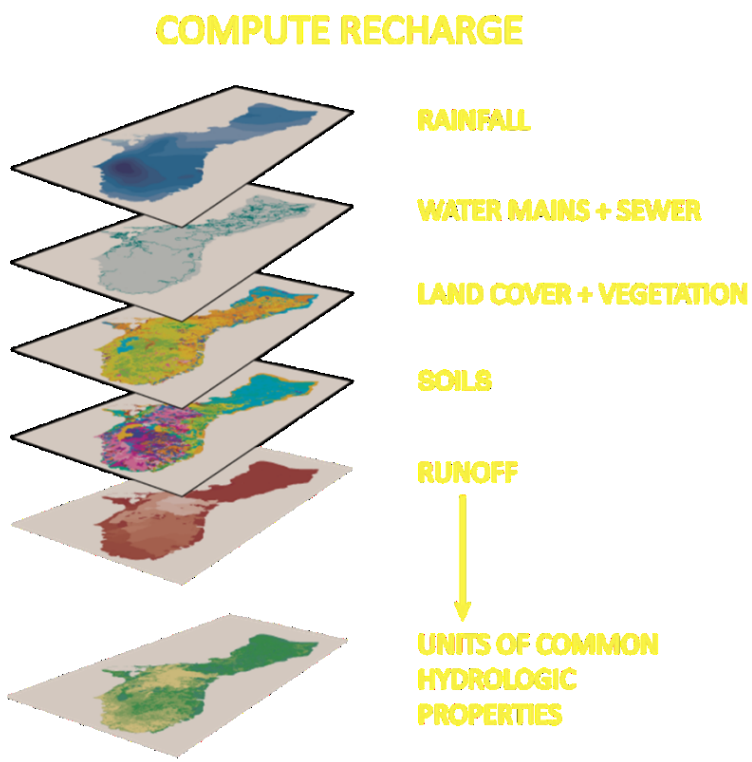


Task 3: Fena Valley Reservoir Capacity

- Knowledge of reservoir capacity based on 23-yr old bathymetry data
- New data collection & analysis needed to update reservoir model
  - Perform bathymetric survey
  - Differential Global Positioning System (GPS)
  - Survey-grade echo sounder accurate to < 1 cm
  - Collect sediment cores at about 10 sites & analyze for bulk density & grain-size distribution
  - Compare new bathymetry to past bathymetry to get sedimentation rate
  - Compare sediment record with typhoon record to correlate events
  - Compare turbidity record with rainfall record to correlate events
- Update reservoir water-balance model
  - Incorporate new reservoir volume
  - Incorporate new streamflow estimates from watershed model
  - Apply a range of projected meteorological conditions to estimate future volumes
  - Evaluate reoccurrence interval for high-turbidity conditions

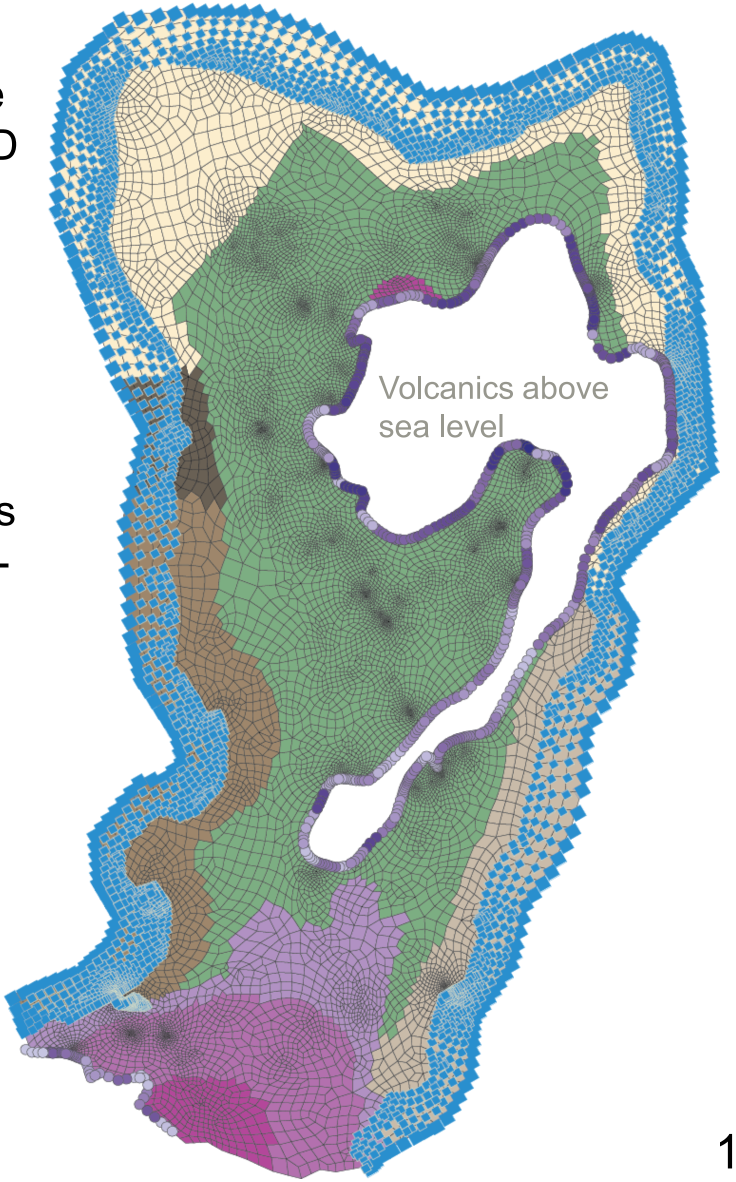
Task 4: Groundwater Geochemistry & Water Budget

- Determining 1) rate & timing of recharge and 2) groundwater flow paths are critical for understanding groundwater resources
- Use geochemical tracers to reveal groundwater flow paths & residence times (fast vs. slow pathways)
- Sample rain, cave drip water, wells, springs, & rocks across northern Guam for cations, anions, Sr & water isotopes; ~100 samples/year for 3 years
- Reevaluate & refine USGS water-budget model to account for fast & slow recharge out of soil reservoir
- Recompute current recharge using refined water-budget model
- Apply a range of projected meteorological conditions to determine a range of future recharge estimates
- New estimates of current & future recharge will be available for the existing groundwater model



Task 5: Northern Guam Groundwater Model

- Recently developed SUTRA groundwater model is the best tool to evaluate future pumping scenarios for DoD & public demand
- Evaluate model using updated current recharge & if needed, recalibrate by adjusting hydraulic properties
- Apply a range of future recharge & sea-level estimates to evaluate the impacts to the salinity of DoD & public-supply wells



Task 6: Adaptive Strategies

- **What are the effects of applying different adaptive management strategies to water-resource management?**

  Surface-water examples

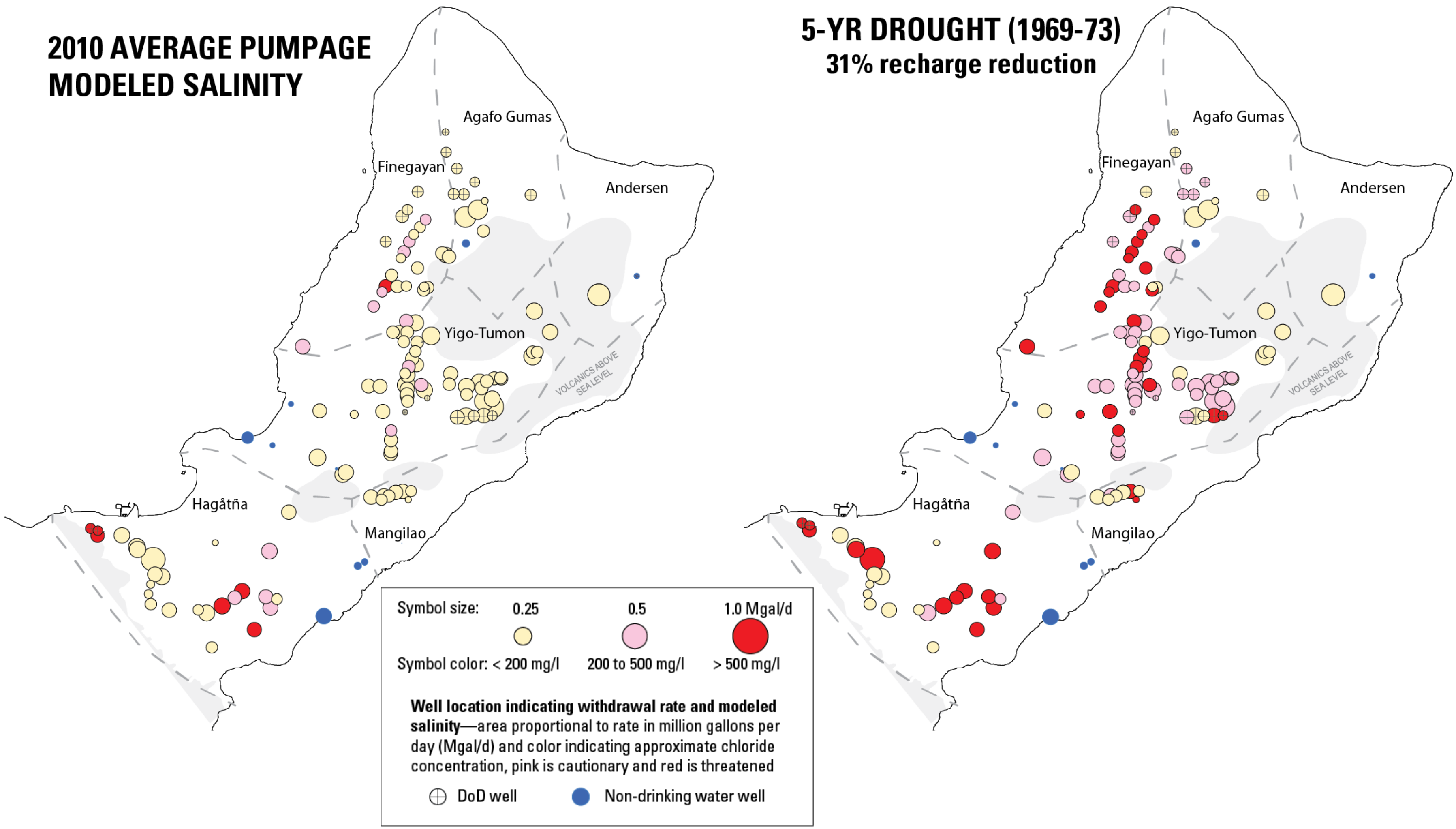
  - Provide estimates of volume increase to Fena Valley Reservoir by:
    - Dredging
    - Raising spillway height
    - Modifying water intake height
  - Provide estimates of expected increases in high-turbidity water episodes requiring treatment

  Groundwater examples

  - Provide estimates of pumping rate & salinity distribution in wells for:
    - “taking no action”
    - Modifying pumping rates at existing wells
    - Replacing wells that are too deep
    - Modifying pump intake depths to account for rising sea level
    - Shifting production to less-vulnerable locations

  Evaluate salinity & volume with conjunctive use of surface water & groundwater

Task 7: Communicating Results



Examples of salinity distribution maps for average & historical drought conditions

Task 7: Communicating Impacts

- Need to link information suppliers & users to improve decision makers’ capacity to use the information generated from this research in their planning & adaptation activities
- Theoretical framework drawn from risk-communication & behavioral-decision research
- Incorporate purposive sampling; in-depth interviews; workshops; online survey
- Assess stakeholder characteristics to understand their current & potential use of climate & other uncertain information
- Assess information characteristics to understand how features of information about the effects of climate change on water conditions influence (1) understanding of potential impacts of climate on estimates & (2) preferences among alternative management solutions
- Assess context characteristics to understand barriers to information use & decision-support needs
- Summarize qualitative & quantitative findings; scenario descriptions (traditional & policy relevant); guidance on scenario development & intended use

Year 1 Project Plan

• Regional climate projections (Task 1)	$59K
• Watershed model (Task 2)	$226K
• Reservoir capacity (Task 3)	$145K
• Groundwater geochemistry & water budget (Task 4)	$97K
• Numerical groundwater model (Task 5)	$0K
• Adaptive strategies (Task 6)	$0K
• Communicating impacts (Task 7)	$83K
• Information transfer/meetings/project management	$71K
	TOTAL $682K

Overall Project Plan

TASK	FY 2014	FY 2015	FY 2016	FY 2017
1. Regional Climate Projections				
2. Watershed Model				
3. Reservoir Capacity				
4. Groundwater Geochemistry & Water Budget				
5. Numerical Groundwater Model				
6. Adaptive Strategies				
7. Communicating Impacts				
SERDP Reports				

Project Funding

$K	SERDP	UH-IPRC
Year 1	682	20
Year 2	505	20
Year 3	673	0
Year 4	419	0
Total	**2,279**	**40**

Deliverables

At least 4 scientific journal publications

- Climate-change modeling & projections
- Geochemical tracers & recharge mechanisms
- Updated & future water budgets
- Groundwater & surface water adaptive management

1 USGS peer-reviewed Scientific Investigations Report

- Watershed model & updated reservoir water balance (functions as a User's Guide)

Training

- 2 Masters students
- 1 post-doc